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ION-ASSISTED DEPOSITION OF OPTICAL THIN FILMS AT DIFFERENT ION BEAM ENERGIES

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Fan Ruiying Lu Yuemei

ABSTRACT

This article, using TiO_2 thin films as examples, studied and analyzed the optical properties, laser damage threshold values, and microstructures of thin films associated with ion assisted sedimentation at different energies.

KEY WORDS Thin Film, Optical Characteristics, Absorption, Scattering, Damage Thresholds, Microstructures, Ion Assistance,
Bombardment Energy

I. INTRODUCTION

TiO_2 is a type of high melting point oxide film material. It has very good transparency in the visible light range and near infrared wave band. In conjunction with this, it possesses high refraction indices and high antilaser damage threshold values. Because of this, it is applied in a relatively wide spread way in laser thin films. However, a large body of research clearly shows that two problems exist with using traditional vacuum evaporation deposition thin films. One is that, due to thin film columnar structures, thin film packing densities are lower than 1, leading to high sensitivity of thin film properties to changes in environmental conditions. A second is that, due to oxide film materials being easily decomposed during evaporation processes, changes in chemical measurements associated with deposition of thin film layers are created, forming a number of oxide metamolecules or ions and leading to film absorption increases. As far as these two problem areas are concerned, they are

* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

extremely disadvantageous for coating property stability and fighting laser damage. However, opting for the use of ion assisted deposition techniques is capable of improving them [1,2].

This article carries out research and analysis of TiO_2 coatings associated with ion assisted deposition at different energies. Results clearly show that the optical properties of these coatings (including refraction indices as well as their changes over time, absorption rates, integral scattering rates, and so on), laser damage threshold values, as well as microstructures all are related to the energies of assisting ion beams.

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II. EXPERIMENTAL CONDITIONS

In the experiments in question, samples were evaporatively prepared using E type electron guns in GDM-450 model film plating devices. The assisting ion source, which was capable of use, was a hot cathode Kaufman source. The experimental set up is shown in Fig.1.

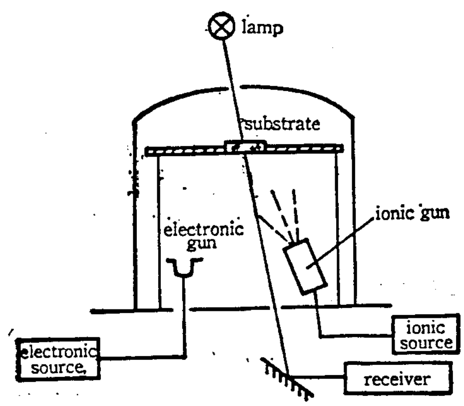

Fig.1 Experimental Arrangement

In the process of sample preparation, substrates are not heated to dry them. As far as the various sample preparation conditions are concerned--besides the energies of the ion

assisting beams used being different--the remaining conditions (for example, degree of vacuum, deposition speed, and so on) are basically maintained the same.

Sample refractive indices are measured using elliptical deviation instruments. Absorption rates are measured using photothermal deflection methods. Integral scattering rates, by contrast, are measured by SSY-1 model laser scattering devices [3]. Laser damage experiments were carried out on Nd:YAG laser systems (wave length was 1.064 μm, pulse width was 10ns, light facula radius was 90 μm). Microstructure analysis was carried out on TEM-200CX model transmission electron microscopes.

III. EXPERIMENTAL RESULTS

3.1 Optical Properties

Table 1 sets out refraction index values and their changes over time for single layer TiO_2 using ion assisted deposition with different energies on K_9 substrate. From these results, it is possible to see that, following increases in ion beam energy, coating refraction indices increase. However, the changes over time still decrease. This clearly shows that relatively high ion beam energies cause relatively compact film layer deposition. Because of this, film stability is, then, also better.

TABLE 1. REFRACTIVE INDEX (λ =0.633mm) VS ION-BEAM ENERGY

ions-beam energy (eV)	Time after deposition (days)					
	1	5	6	7	11	15
	refractive index					
0	2.017	2.036	—	—	2.057	2.073
200	2.022	2.036	2.043	2.045	2.058	2.077
400	2.106	2.120		2.129	—	2.164
600	2.314	2.334	2.338	2.336	—	2.336
800	—	2.329	2.325	2.328	2.336	2.336

Table 2 sets out film absorption rate A, integral scattering rate S, and surface roughness σ for single layer TiO_2 films associated with deposition assisted by different ion beam energies. Here, absorption rate is a relative value. Taking sample absorption rates--under the same type of preparation conditions--which have not yet added ion assistance (that is, J = 0), and seeing them as 1, the rest are relative to it, and nothing more. From these results, it is possible to see that: (1) With regard to samples for which ion beam energies are 200eV and 400eV, absorption rates are clearly reduced. As far as samples associated with ion beam energies which are 50eV and 600eV are concerned, absorption rates are basically in line with samples which have not added ion assistance; (2) In ranges where ion beam energies are lower than 800eV, the higher ion beam energies are, the lower sample integral scattering rates are. Also, the higher coating surface smoothness will then be. This result fits with observation results using transmission electron microscopes on coating surface appearances.

TABLE 2. ABSORPTION, SCATTERING AND SURFACE ROUGHNESS VS ION-BEAM ENERGY

ion-beam energy (eV)	relative absorptance (λ=632.8 nm)	scattering (10^{-4}) (λ=632.8 nm)	surface roughness (nm)
0	1	11.74	1.73
50	0.94	9.339	1.55
200	0.64	7.272	1.37
400	0.56	5.834	1.22
600	1.22	4.184	1.04
800	2.22	11.91	1.75

3.2 Microstructures

Fig.2 gives surface appearances and diffraction patterns for three types of different thin film samples observed and

photographed using transmitive electron microscopes. Results clearly show that assisted samples using 200eV and 600eV ion beams as well as conventional samples which have not added ion assistance (substrate temperatures approximately 250°C) both display an amorphous crystalline structure. However, their particle dimensions still show relatively large differences. 600eV ion beam assisted film granularity is approximately 1 fold smaller than 200eV. This is precisely the reason why coating layer scattering rates related to granularity then clearly diminish.

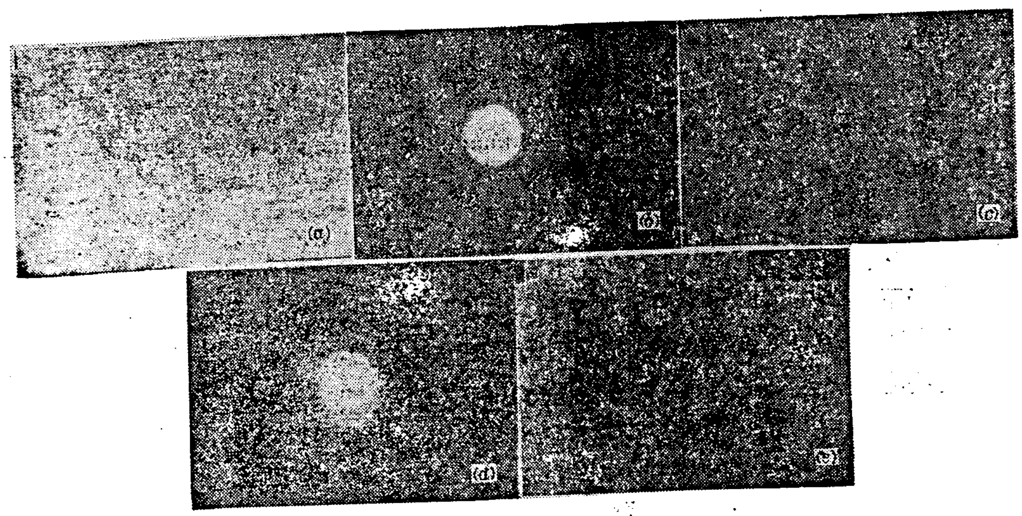

Fig. 2 Microstructures vs bombardment energy

(Photographed by jem 200 X transmittive electron microscope/50000 ×). (a)、(c)、e)-morphology observed, (b)、(d)-electron diffraction pattern. (a)、(b): ion-beam: 200 eV; (c)、(d): ion-beam: 600 eV; (e) traditional vacuum deposited sample

3.3 Laser Damage Threshold Values

Table 3 sets out damage threshold values for TiO_2 coating layers deposited using ion assistance under the effects of 1.064 μm lasers. Results clearly show that 200eV ion beam assistance samples possess the highest damage resisting threshold values. The threshold values are approximately two fold those of samples not adding ion assistance. However, 600eV and 800eV assisted sample damage threshold values were the lowest. They were approximately 30% of samples not adding assistance.

TABLE 3. LASER-INDUCED DAMAGE THRESHOLD VS ION-BEAM ENERGY

ion-beam energy (eV)	0	50	200	400	600	800
LIDT(J/cm^2)	7.39	7.07	16.5±2.0	7.86	5.03	5.03

IV. CONCLUSIONS

Experimental results clearly show that ion assisted deposition technique improvements to TiO_2 coating quality strongly depend on ion beam energies. When energies are relatively low--for example, 50eV--in that case, ion beam bombardment effects are very weak. When energies are relatively high--for example, 800eV--in that case, ion beam bombardment will bring harm to coatings. Because of this, when opting for the use of ion assisted technology, it is necessary, on the basis of actual requirements, to select appropriate ion beam energies.

The experiments in question also make it possible to see that there certainly is no simple relationship between laser damage threshold values associated with studied coatings and measured absorption rates, scattering rates, or microstructures. Internal mechanisms await further study.

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